The sensitivity of initial thermal perceptions when altering local skin temperatures by modifying microclimate relative humidity

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INTRODUCTION

It is known that humans have no receptors that allow them to directly sense changes in relative humidity (RH) (Nielsen and Endrusick 1990). Changes in microclimate relative humidity surrounding the skin affect the body's ability to lose heat and therefore influence skin temperature and eventually core temperature. Previous work has shown that RH may be sensed through changes in skin heat flux (de Dear and Ring 1990), indirectly through skin temperature sensation (Newton, Davey et al. 2007) and additionally hyper-hydration of the skin (Shibasaki, Wilson et al. 2006).

Many researches have studied regional temperature sensation, for review see (Hensel 1981), far fewer have studied how perception is affected by altering microclimate RH (Fanger 1970; de Dear, Knudsen et al. 1989; Toftum, Jørgensen et al. 1998). Previous experiments in our laboratory have shown how both temperature sensation and thermal comfort are modulated by changing microclimate RH.

This investigation sought: to modify skin temperatures by various methods; compare how thermal and non-thermal perceptions interact: to identify if perception differences exist between different heat loads with the same microclimate RH.

It is hypothesized that:

i. Differences in thermal perceptions can be predicted on the basis of altering the local skin temperatures of small regions of the torso through fixed changes in microclimate relative humidity.

ii No difference in thermal perceptions will be observed between raising the local skin temperature of different torso regions or changing the core temperature when local skin temperature is altered by microclimate relative humidity at controlled rates.

METHODS

Having received ethical approval, 9 male volunteers completed the protocol. Participants were clothed throughout the experiment in briefs, lightweight synthetic athletic trousers, footwear, and socks, total insulation ~ 0.3 clo. The experiment was run in an environmental chamber at 33^{o}C, 80% RH. Silicon exposure vessels, 13cm diameter, 132cm^{2} in area, and 1cm deep with an air inlet and outlet vent were sealed to the upper chest and abdomen. Participants were instrumented to measure local (T_{skinl}), and mean (T_{skinm}) skin temperature, local microclimate relative humidity (RH_{loc}), rectal temperature (T_{core}) and heart rate (fc).

The experiment consisted of three periods: Phase 1 - resting in a warm chamber with chest and abdomen exposed to modified microclimates using silicon vessels; Phase 2 - a short self paced 10 minute run, where the bare chest was then exposed to modified microclimates through air perfusion; Phase 3 - a repeat of Phase 1 exposure. Perceptual measurements were assessed during the experiment using verbal instructions when changes in temperature sensation were experienced. The experiment exposure profile is shown in Figure 1.

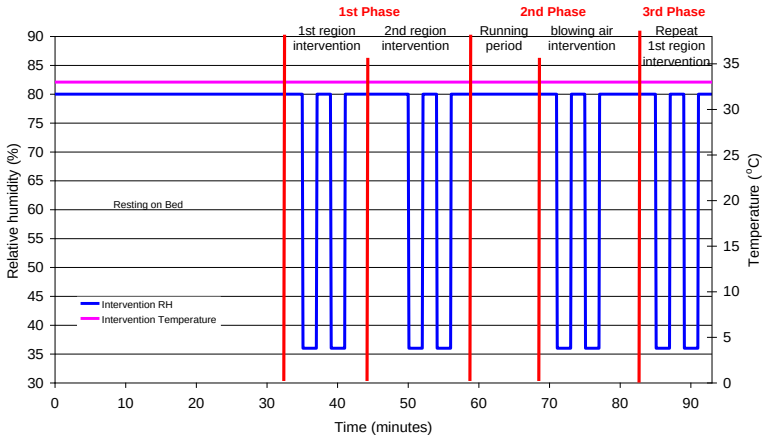

Figure1 - Experimental intervention profile for microclimate temperature & RH

Phase 1: Resting phase - Volunteers lying supine while regions of the torso were exposed to modified microclimates. This phase was designed to enable changes in local microclimate RH without significantly impacting mean skin temperature. During this period ambient air was initially perfused through the exposure vessels. Air flow rate was maintained at a rate of ~1.75L.s^{-1} to create a homogenous microclimate and normalize local skin wettedness within the vessels. After the local skin temperature had stabilized the RH was altered (flow rate the same) using a y-valve connected to a custom-made air conditioning unit.

Phase 2: Exercise Phase (treadmill) - A 10 minute self-paced run followed by a 15 minute walk at 5km.hr^{-1} and 1% incline. During the walk, air of varying temperatures and RH was blown over an area of the chest. A constant flow of air was perfused around the chest via a tube mounted on the treadmill 30cm in front of the participant. Modified temperatures and RH were designed to elicit local skin temperature changes of ~1^{o}C. Thermal comfort and

temperature sensation measurements were measured via touch screen scales described previously (Newton, Davey et al. 2007) during this phase.

Phase 3: Resting phase with high skin wettedness – This Phase was a repeat of Phase 1 but was designed to enable larger changes in local skin temperature due to presence of sweat on the skin. The air flow rate was initially controlled at 33^{o}C, 80%RH to create a homogenous microclimate and normalize the skin wettedness within the vessels. RH through the vessels was then manipulated and the impact on T_{skinl}, comfort and temperature sensation measured.

Deep body temperature was measured via a rectal thermistor inserted 10cm beyond the sphincter, mean skin temperature was calculated from skin temperatures measured at 5 sites using digital thermometers DS18B20, RH was measured using SHT15 digital sensors, and heart rate was measured using a polar strap. All data was logged to an MSR 12 data logger.

Volunteers experienced either an increase or decrease of 44% RH (at 33^{o}C) throughout the experiment on the upper chest or abdomen. All experiments also included "fake" changes of 0% RH to ensure there was no response to equipment manipulation, in all cases the fake changes had no influence on temperature sensation. Repeated measures were taken both pre and post exercise to determine both fatigue and the effect of increased core temperature. Temperature sensation was selected from a ten point scale with intervals identified between cold and hot (determined from previous work in our laboratory), each of these points were assigned values between -5 and +5.

Local skin temperature and microclimate RH values were then identified for the beginning and end of each intervention, as well as the time taken for these changes to occur.

RESULTS

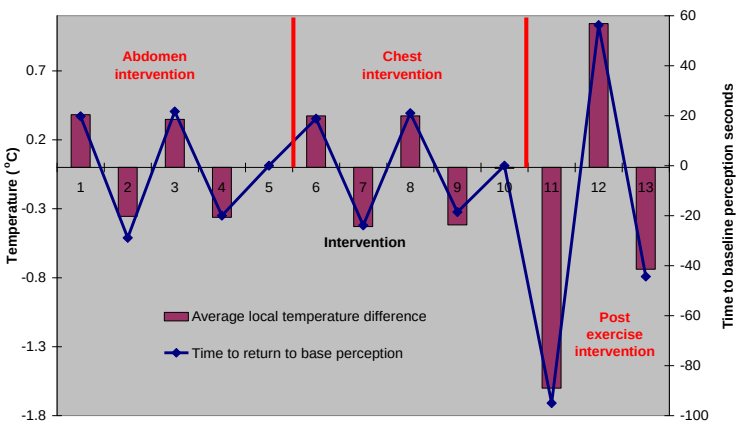

Figure 2 - Average t_{skinl} difference vs. time taken for temperature sensation return to baseline (n = 9)

For 99% of the data, average rates of change of T_{skinl} were found to fall within a range of 0.015 – 0.035^{o}C.sec^{-1}. Figure 2 shows the relationships between local skin temperature changes and the time taken for volunteers to return to their pre-intervention baseline perceptions.

The temperature perceptions reported using perception scales and the time taken for volunteers to return to their baseline perceptions were then used as model response variables, while changes in skin temperature and microclimate RH, rate of change of skin temperature and RH, pre and post exercise, body region measured, and participant were used as model factors. A general linear model was constructed to determine the most significant factors.

This model highlighted that one of the nine participants had very different results from all other 8, if the model was run without this individual's data a R^2 correlation of 0.94 was found between the time taken for participants to return to baseline perception and change in local skin temperature. If however this participant's data were included, then "Participant" had to be included as a factor in the model. Figure 3 shows the data including all participants (n=9) and shows a R^2 correlation of 0.92 using these two factors and response.

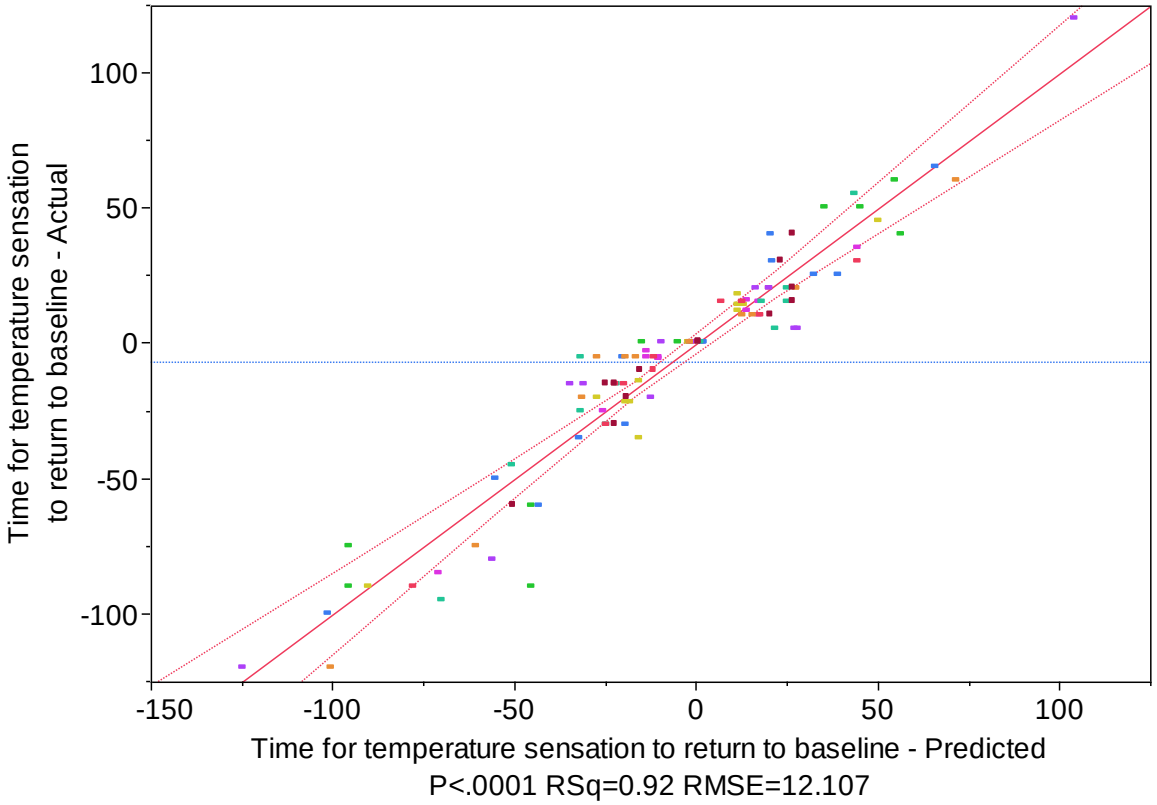

Figure 3: Linear model of time to return to baseline predicted by change in T_{skinl} and participant

CONCLUSIONS

This study demonstrates that initial perception of microclimate RH is linked primarily to the rate of change of local skin temperature, with over 90% of the intervention effect being explained directly through this single variable.

Rates of change in local skin temperature all fell within the small range of 0.015 – 0.035^{o}C.sec^{-1} and therefore the strength of a response can be approximated by the size of a

local skin temperature change (by altering microclimate RH) and how this relates to the time an individual's temperature sensation took to return to their pre intervention baseline level. All interventions used a constant 44% RH difference, and temperature sensation differences varied widely confirming that volunteers were not responding to the RH change directly, we therefore reject our first hypothesis.

Further, pre and post intervention local skin temperatures were always different, between 0.25–1.9^{o}C, but in over 99.5% of our interventions participants always returned to their pre intervention temperature sensation, suggesting that within this range, only rate of change of skin temperature and not skin temperature itself was influencing thermal perception.

Finally model data only showed strong relationships between the strength of temperature sensation measured by time to return to baseline compared to the size of the local skin temperature change, while region of the torso, pre and post exercise, and size of the RH change all showed no, or very weak relationships to both response variables, we therefore accept our second hypothesis.

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